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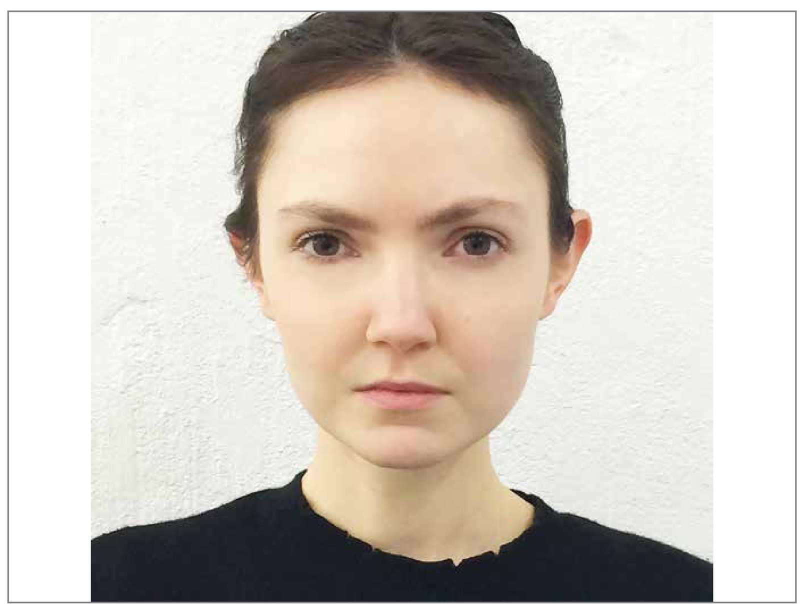
Evaporative Big Box

Prototype for a cooling roof, Princeton, NJ, USA



Main author

Georgina Baronian, student, Princeton University, Princeton, NJ, USA

Project data

Project group: Materials, products and construction technologies
Client: Private client/building technologies company
Project background: Research project

Summary and appraisal of the project by the jury

Taking on the challenges of logistics centers at the periphery of cities as a point of the departure, the project unfolds as a research undertaking investigating the question of how to cool large structures with minimal means. With the objective in mind to reduce the building's energy load, (particularly the deployment of non-renewable resources), a thin layer of water is introduced as an additional roof layer – acting as a solar reflector, while providing thermal insulation. Whereas technical considerations are at the core of the project, the study culminates in a design of a big box structure that is as reduced in its formal manifestation as it is beautiful in its aesthetic simplicity.

The project's visionary stance caught the jury's attention. Acknowledging the research's underlying critique pertaining to the inefficiency of complex and complicated mechanical systems in the contemporary building sector, the jury applauded the project's thesis as well as choice of case study. Particularly valued was the set of ideas put forth concerning the detrimental impact of climate control technology on human-induced climate change. Moreover, the jury appreciated the relation established between the project's scientific method of approach and the design's formal appearance – the poetry of construction details and the presence of the architectural object at the territorial scale.

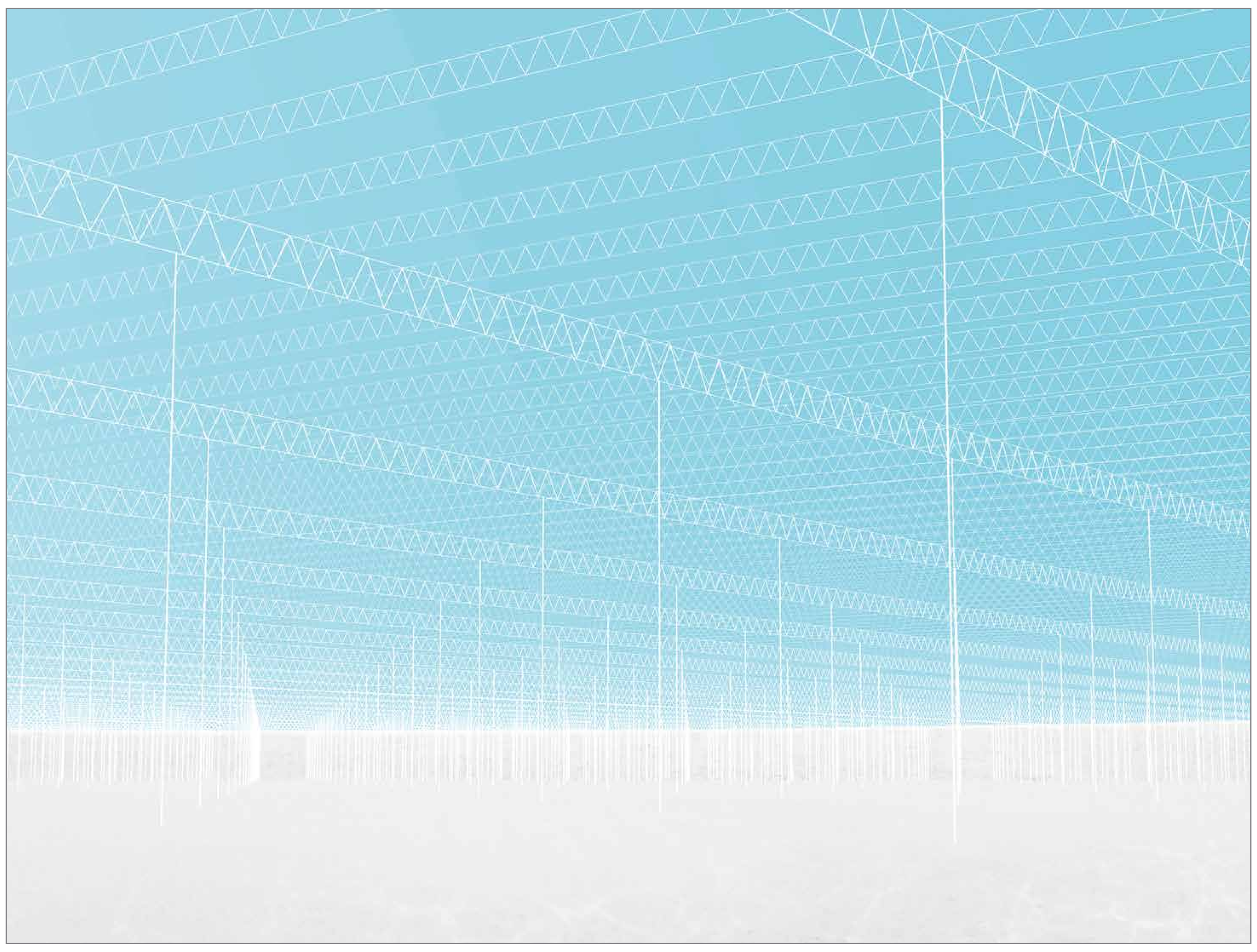


Image 1: Atmospheres of climate: Harnessing the absorption and transmission properties of water, which mirror that of low-E glass, the proposal allows light in the visible spectrum to provide natural daylighting while blocking ultraviolet and infrared radiation. A unique quality of light would be achieved, the gentle movement of the water above transmitting the atmosphere of the day outside within and allowing the expression of the temporal nature of climate.

Statements on the sustainability of the project by the author

An integrated approach to energy, climate & aesthetics
The project considers the relationship between energy infrastructures and the spaces they serve, developing an integrated solution that not only engenders efficiencies but proposes a new methodology for the construction of atmosphere. The modernization and mechanization of architecture over the course of the 20th century has resulted in complex buildings systems, progressively removed from the spatial experience and obtuse to the user. This separation of occupant and system accounts in part for the misuse of energy resources within the built environment today. Through the establishment of a climatic device that modifies both interior comfort and spatial experience, linking to "Progress" and "Place" the proposal seeks to conceptualize a new way of producing sustainable building systems.

Reconsidering the production of interior comfort
At the heart of the project is the desire to harness the latent potential of natural systems, in place of the ever-increasing use of energy demanding mechanical systems, connecting to the target of "Planet". Through understanding the evaporative properties of water in the context of the psychometric chart and creatively interpreted in the design of a passive building system, the project strives to provoke new directions and methodologies for the construction of climate. In analogue with the target of "People", the project through its use of radiant cooling (which does not alter air temperature but modifies its perception) also questions our assumptions of how comfort is created and indeed what comfort is.

Energy infrastructures as landscape
Architecture's ever-increasing reliance on secondary infrastructures of scale renders explicit a growing disjunction of needs, resources and design. This leads to a necessary reevaluation of our programmatic, climatic and energetic relationships. Speculating on the complete elimination of the requirement for a secondary infrastructural architecture, the case study shows that when considered at scale the prototype would act an independent infrastructure – the energy needs of the total floor area would be met within the architecture itself, using a volume of water comparable in magnitude as that of a cooling tower constructed to serve that same area. Furthermore, the case study considers a climatic envelope deployed as a beautiful, shimmering moonlike landscape, linking "Planet" and "Place".

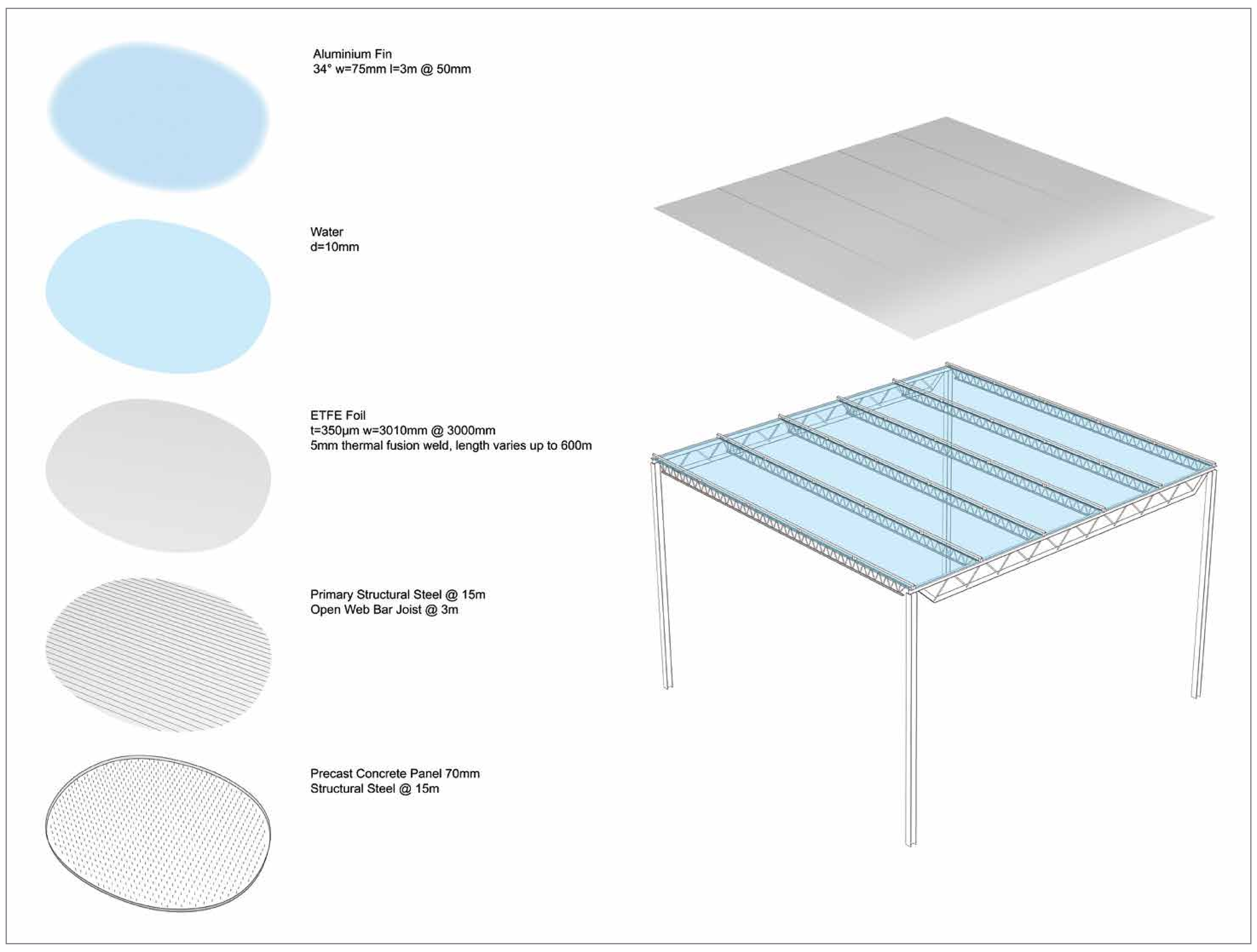


Image 2: Reconsidering comfort: An evaporating layer of water on the roof approaches a wet bulb temperature of 12°C (a typical roof reaches 60-100°C), mitigating the albedo effect. Ambient indoor temperature is approx. 50 % radiant heat from surface radiation and 50 % air temperature. Interior space with a view factor to the roof only would be fully climatized. With an indoor air temperature of 25°C, a mean radiant temperature of roof and floor of 18.5°C, the ambient indoor temperature of 21°C is achieved.

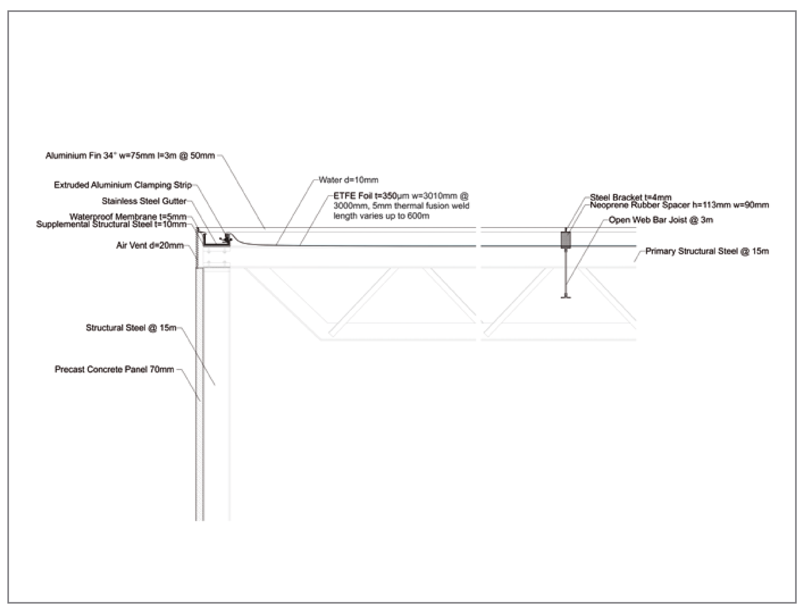


Image 3: Prototype structure: A simple construction supports 10mm water layer atop 97 % transparent EFTE foil.

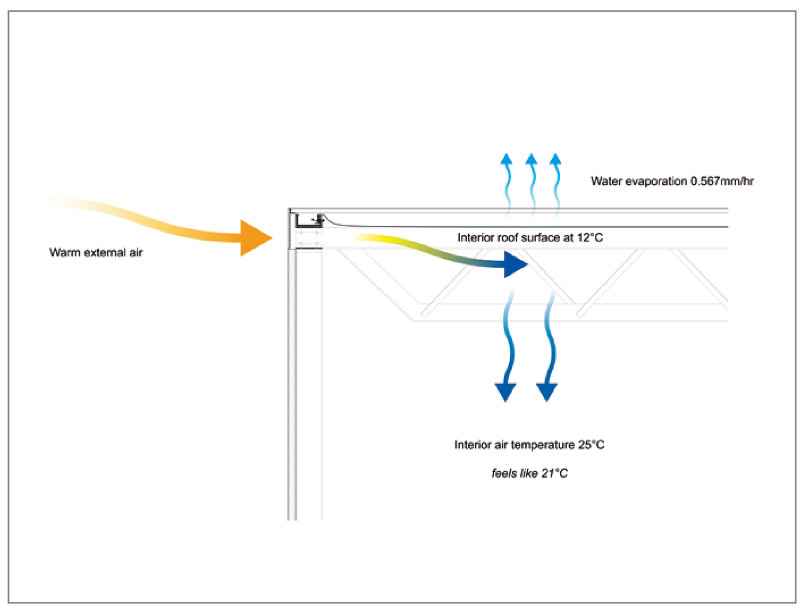


Image 4: Interior comfort: The evaporative water surface passively cools the interior through radiant cooling.

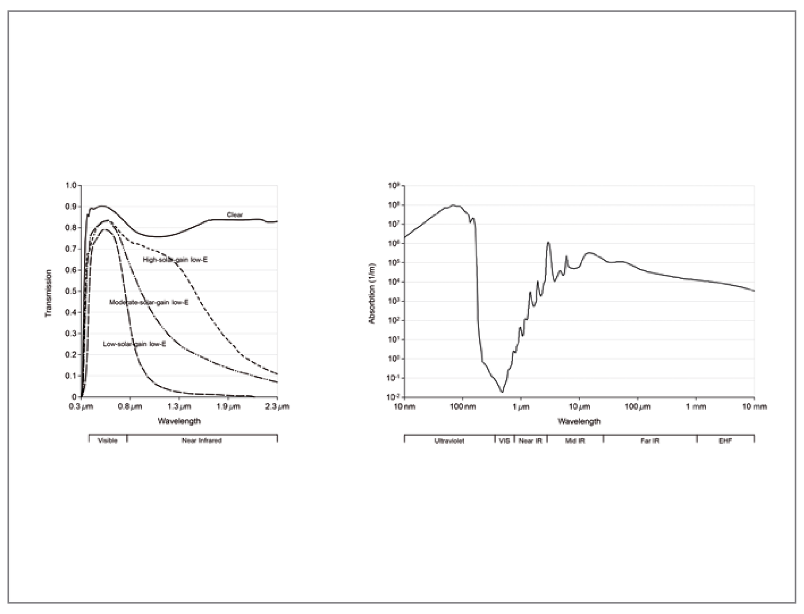


Image 5: Daylighting: Transmission properties of water reduce total energy use through natural daylighting.

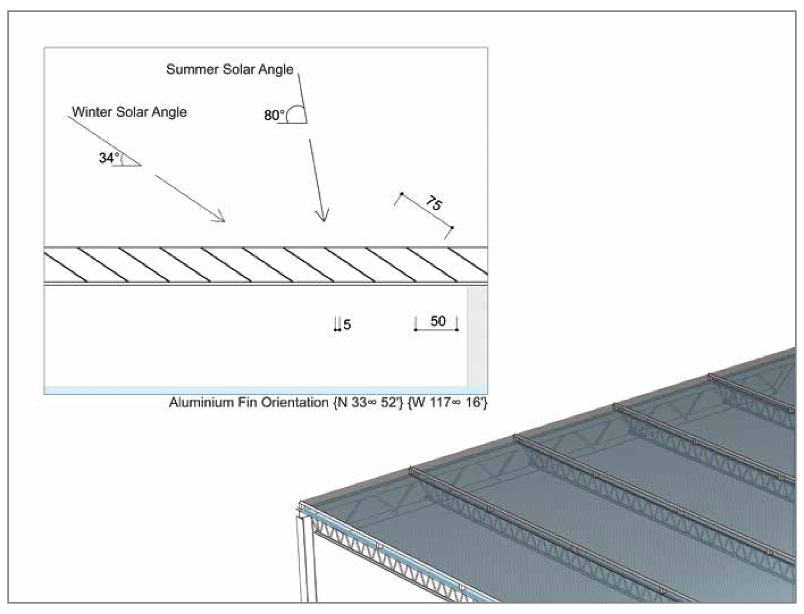


Image 6: Aluminum fin orientation: Shades water for max. cooling during summer but max. daylighting in winter.

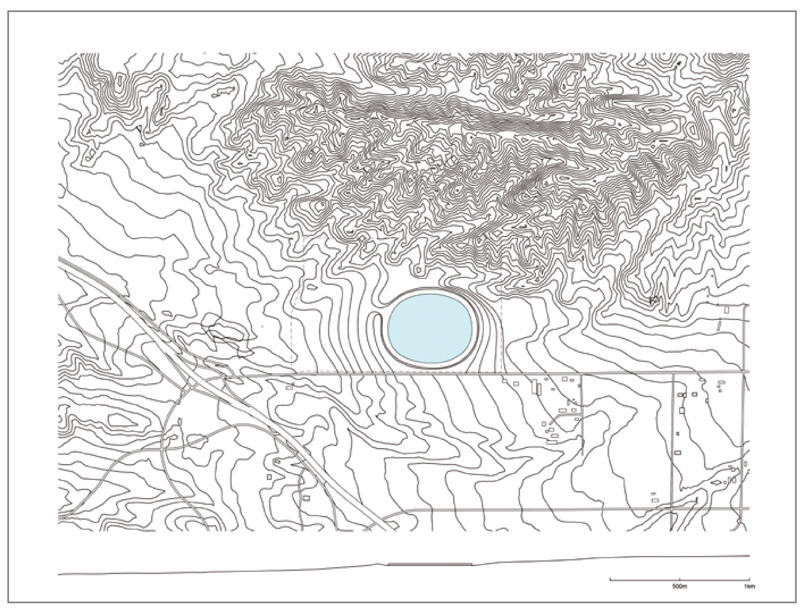


Image 7: Case study: 240,000 m² I-10 logistics center, Cherry Valley, California, USA - site plan & section.

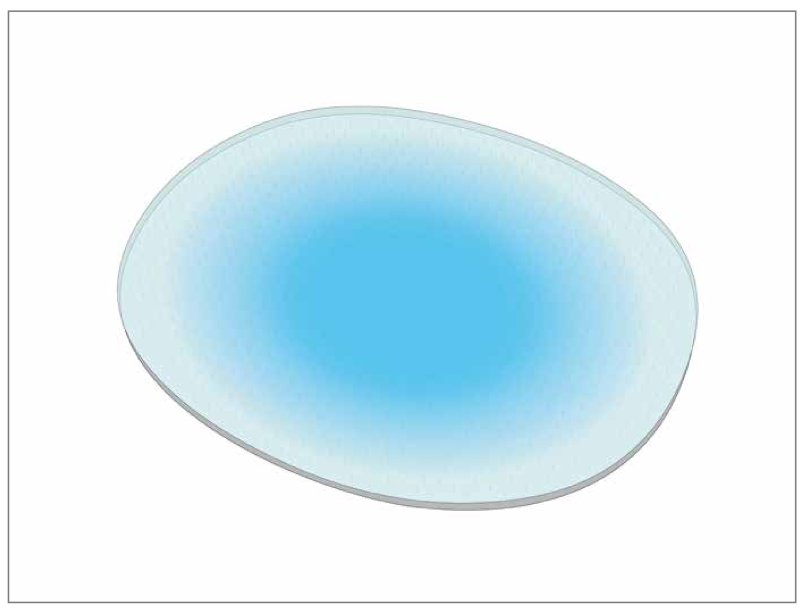


Image 8: Case study: A circular plan maximizes fully climatized area, with semi-climatized loading at perim.

	weather condition (evaporative potential)			
	low (wet + no wind)	nominal (ave + ave wind)	high (dry + higher wind)	
v (wind)	0	2	5	m/s
Θ (evaporation coefficient)	25	63	120	
x_s (humidity ratio saturated air)	0.011	0.015	0.016	H_2O / kg air
x (humidity ratio air)	0.009	0.006	0.005	H_2O / kg air
A (area)	237,831	237,831	237,831	m²
evaporation	11,892	134,850	313,937	kg/hr (litres/hr)
	3.3	37.5	87.2	kg/s (litres/s)

Rate of water loss on roof (nominal weather conditions) = 134.850 m³/hr
= 0.567mm/hr

	weather condition (evaporative potential)			
	low (wet + no wind)	nominal (ave + ave wind)	high (dry + higher wind)	
latent energy of evaporation	2257	2257	2257	kJ/kg of water evaporated
energy removed from roof	7,455	84,544	196,821	kW
	31	355	828	W/m²

Heat gain from air is ~10-50 W/m2. Consider sun provides ~100 W/m2 (from 0 to 800 W/m2).
Typical black roof 60-100°C, typical white roof 40°C.
Water surface approaches wet bulb temperature = water roof 12°C.

Image 9: Case study: Evaporative potential (avg. 0.5mm/hr) & resultant energy removed (avg. 355W/m²).

Image 10: Case study: The integrated climate device provokes potential for energy infrastructures as landscape.